

NEW ACTIVE REMOTE-SENSING CAPABILITIES: LASER ABLATION SPECTROMETER AND LIDAR ATMOSPHERIC SPECIES PROFILE MEASUREMENTS. R. J. De Young and J. T. Bergstralh, Science Directorate, NASA Langley Research Center, MS 401A, Hampton, VA 23681, [russell.j.deyoung@nasa.gov](mailto:russell.j.deyoung@nasa.gov), [jay.t.bergstralh@nasa.gov](mailto:jay.t.bergstralh@nasa.gov)

**Introduction:** With the anticipated development of high-capacity fission power and electric propulsion for deep-space missions, it will become possible to propose experiments that demand higher power than current technologies (*e.g.* radioisotope power sources) provide. Jupiter Icy Moons Orbiter (JIMO), the first mission in the Project Prometheus program, will explore the icy moons of Jupiter with a suite of high-capability experiments that take advantage of the high power levels (and indirectly, the high data rates) that fission power affords. This abstract describes two high-capability active-remote-sensing experiments that will be logical candidates for subsequent Prometheus-class missions.

**High-Energy Laser Pump Source:** Both experiments incorporate a high-energy laser as a pump source. High-energy laser pump sources are currently being developed for military and for industrial processing purposes. From the standpoint of technical maturity, they could be reasonably proposed for space science missions in the near future. However, they are inefficient and consequently require the high power levels afforded by fission. An example is the Yb:YAG master oscillator power amplifier system developed by Raytheon under DARPA sponsorship. In this case, a 25 kW breadboard laser was demonstrated at 1029 nm with efficiency of ten percent. The laser system’s Q-switched output is 25 J per pulse and it has good beam

quality ( $M^2 = 1.5$ ). As tested, this system occupies a volume of 114 x 152 x 45 cm, but it could be made substantially smaller for space applications. This laser could be the pump source for the following instruments.

**Laser Ablation Mass Spectrometer:** High-energy pulses from the Yb:YAG laser, focused by a 2 meter diameter transmission mirror, would produce energy densities of the order of  $10^9$  Watts  $\text{cm}^{-2}$  on a surface at a distance of 100 km. The resulting plasma would generate ions of sufficient energy and quantity to be detected with a mass spectrometer on the spacecraft [1,2]. This would make it possible to map with very high spatial resolution the elemental compositions of the surfaces of planetary bodies without atmospheres. Figure 1 shows an experimental example of a laser ablation mass spectrum taken at 18 m with a Nd:YAG laser.

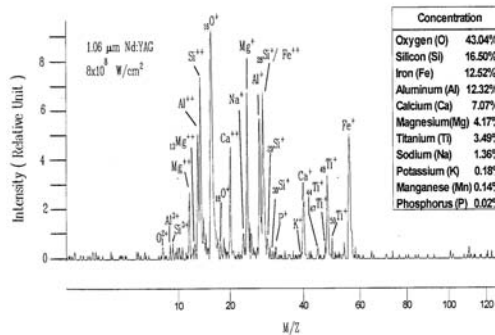


Fig 1. Laser ablation mass spectrum of lunar stimulant from [1]. The table list the manufactures measured concentrations.

### **Lidar Profiling of Atmospheric**

**Species:** The Yb:YAG laser can be operated at almost any power level up to 25 kW. Thus, this laser could also be used to pump an optical parametric oscillator/amplifier (OPO) to produce single-frequency pulses for a differential absorption lidar (DIAL) experiment, to measure the atmospheric abundance of almost any molecular species of interest.

For example, there have been several recent reports of detection of methane in the martian atmosphere [3,4,5]. Methane has a short lifetime (~350 yr) in the martian atmosphere, so some source must replenish it. This is potentially important because methane can be produced by biological processes as well as by non-biological processes. A DIAL experiment in orbit around Mars could detect small variations in methane concentration near the surface, giving clues to its source(s). The OPO would be pumped at 1029 nm. For the on-line DIAL wavelength, a signal seed laser would generate pulses at 1.5 micron that would result in an idler wavelength of 3.3 microns (*i.e.* the wavelength of the strong methane  $\nu_3$  fundamental). The off-line DIAL wavelength would be generated by slightly changing the signal seed laser wavelength.

Another important problem is the distribution of water vapor in the martian atmosphere. This could be investigated with high sensitivity using the DIAL technique. In this case, the OPO would be pumped by a frequency-doubled Yb:YAG laser at 514.5 nm. For the on-line wavelength, a signal seed laser at 1128 nm would result in an idler output of 946 nm (the wavelength of a strong water vapor absorption line). Again, the off-line wavelength could be generated

by slightly tuning the wavelength of the signal seed laser. The OPO/amplifier would have to produce about 100 mJ per pulse to accomplish water vapor measurements from Mars orbit.

**A Mission Scenario:** The same Yb:YAG laser used to pump a DIAL experiment could also be used ablate the surface of an airless moon. Combining a laser ablation mass spectrometer and a DIAL lidar in one package would provide a potent capability for investigating planetary *systems*, including atmospheres, rings, and satellite surfaces.

**References:** [1] De Young R.J. and Situ W. (1994) Appl. Spectro., 48, 1297-1306. [2] Situ W. and De Young R.J. (1995) Appl. Spectro., 49, 791-797. [3] Formisano V., Atreya S., Encrenaz T., Ignatiev N., Giuranna M. (2004) Science, 306, 1758-1761. [4] Krasnopolsky V.A., Maillard J.P., Owen T.C. (2004) Icarus 172, 537-547. [5] Mumma M.J., Novak R.E., DiSanti M.A., Bonev B.P., Dello Russo N., (2004) Bull. Am. Astro. Soc. 36, 1127.